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EXTRACTED VERSION

OPERATION SUN BEAM
SHOT LITTLE FELLER II
PROJECT OFFICERS REPORT—PROJECT 1.5

DEBRIS THROWOUT

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U.S. Army Engineer Research
and Development Laboratories
Fort Belvoir, Virginia

15 April 1965

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The primary objective of this project was to collect data on the range and dispersion of blast-driven surface debris in order to assess the significance of surface missiles, as a casualty-producing source from near surface nuclear bursts. The project covered only the range and dispersion of objects having various sizes, shapes, and weights, and excluded such information as flight path, effect of wind velocity, and drag characteristics.

Since this was a first-time experiment for this type of debris hazard, conclusions had to be somewhat presumptive. However, it was established that the debris has no consistent pattern of directional dispersion, that effective distance at which missiles would produce a serious hazard to field personnel is less than 350 feet from ground zero, and small objects on the surface of the ground 150 feet or more from a burst of this type should not pose a serious missile hazard. It was concluded that tree branches would pile up, tending to form a barrier at some undetermined distance from ground zero. Projected area is a more important factor than anticipated and appears to be a prime factor in establishing criteria for missile

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FOREWORD

Classified material has been removed in order to make the information available on an unclassified, open publication basis, to any interested parties. The effort to declassify this report has been accomplished specifically to support the Department of Defense Nuclear Test Personnel Review (NTPR) Program. The objective is to facilitate studies of the low levels of radiation received by some individuals during the atmospheric nuclear test program by making as much information as possible available to all interested parties.

The material which has been deleted is either currently classified as Restricted Data or Formerly Restricted Data under the provisions of the Atomic Energy Act of 1954 (as amended), or is National Security Information, or has been determined to be critical military information which could reveal system or equipment vulnerabilities and is, therefore, not appropriate for open publication.

The Defense Nuclear Agency (DNA) believes that though all classified material has been deleted, the report accurately portrays the contents of the original. DNA also believes that the deleted material is of little or no significance to studies into the amounts, or types, of radiation received by any individuals during the atmospheric nuclear test program.

ABSTRACT

To assess the significance of surface missiles as a casualty producing source from very low-yield, near-surface, nuclear bursts was the primary objective of this experiment. Test objects which consisted of cylinders, cubes, plates, and various building materials were placed in a pattern around ground zero and, by locating these objects and determining reactions and displacements, the significance of this hazard was evaluated.

This was the first experiment of this type to investigate solely blast-driven surface debris. Results showed that twenty percent of the test objects were displaced a distance of 300 feet or more from ground zero. The maximum displacement was 711 feet.

In addition to the objects, tree branches were placed at varying heights above the ground surface and at varying distances out to 200 feet from ground zero. Large poles were used to hold the branches perpendicular to radial lines extending out from ground zero. The maximum branch displacement was 420 feet from ground zero, and twenty percent of all branches were displaced over 260 feet from ground zero.

Since this was a first-time experiment for this type of debris hazard, conclusions had to be somewhat presumptive.

However, it was established that the debris has no consistent pattern of directional dispersion, that effective distance at which missiles would produce a serious hazard to field personnel is less than 350 feet from GZ, and small objects on the surface of the ground 150 feet or more from a burst of this type should not pose a serious missile hazard. There is evidence that missile hazard did not constitute the governing casualty-producing factor for this type of burst. In addition, it was concluded that tree branches would pile up, tending to form a barrier at some undetermined distance from ground zero, projected area appears to be the controlling factor in establishing criteria for missile production, and that additional studies and experiments are required to more thoroughly understand the behavior of missiles created by very low yield nuclear bursts.

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DEBRIS THROWOUT

INTRODUCTION

OBJECTIVES

The primary objective of this project was to collect data on the range and dispersion of blast-driven surface debris in order to assess the significance of surface missiles, as a casualty-producing source from yield, near surface, nuclear bursts.

This investigation was necessarily restrictive, due to its status and the initial step into studying this phenomena. It was not possible to investigate the complete scope of this field, and important factors had to be left open for later study. This project covered only the range and dispersion of objects having various sizes, shapes, and weights, and excluded such information as flight path, effect of wind velocity, and drag characteristics.

BACKGROUND AND THEORY

With the advent of small tactical-size nuclear weapons, a knowledge of battlefield-type missile reaction has become necessary. This knowledge must include missiles most likely found under battlefield conditions, including rocks, tree branches, and building materials. Very few studies have been conducted in this

particular area and most of these were concerned with biological interest and they have dealt primarily with missiles of minute size, i.e., glass fragments and gravel. Three such studies previously conducted were: Operation Teapot (Reference 6) and two projects in Operation Plumbbob (References 7 and 8). As a part of Operation Plumbbob (Reference 8), stones ranging in weight from 0.375 to 42.34 pounds were subjected to dynamic pressures of from 0.25 to 53.5 psi and investigated for displacement. Additional information concerning blast-produced missiles was obtained as a result of the atomic detonations over Japan (Reference 10) and some accidental chemical explosions. These studies were also basically concerned with fragmentary missiles.

Recent studies have been conducted to produce some knowledge about the battlefield-type missile. In addition to the project reported on herein, the study of movement behavior of ideal natural objects was conducted in Project 1.5, Danny Boy (Reference 2). This study was carried out in connection with a deeply buried device and was basically aimed at studying the throwout from within the crater zone. Another recently completed study is an investigation of structural debris distribution produced by accidental explosions and experimental detonations; also, specific estimates are made of the debris hazard to troops by flying tree limbs (Reference 9).

PROCEDURE

There are several variables which affect the path of travel of a missile. These variables include projected area, mass, drag and friction forces, blast force, and duration. By making assumptions and assigning constant ideal condition values for these variables, displacements can be calculated which under actual conditions would seldom, if ever, be attained; however, it is impractical to calculate displacements for all possible casualty producing missiles in the blast area.

OPERATIONS

An assortment of objects consisting of cylinders, cubes, plates, tree branches, and various building materials were utilized as test subjects for this experiment. These objects were placed in different orientations at various distances along radial lines from ground zero. A complete tabulation of all test subjects is presented in Table 1, including shape, size, number, and average weight. Figure 1 is a view of some typical objects placed at the test site. The test objects were painted fluorescent colors to assist in postshot locating and identification; also, each object was measured, weighed, and number coded. Tree branches were number coded with metal tags.

LAYOUT

The preshot layout of the test array was accomplished using standard survey methods, i.e., transit and tape. As

depicted in Figure 2, three concentric circles were staked at 20-, 100-, and 200-foot intervals from ground zero. Radial lines spaced at 15° intervals were marked and staked. These lines extended from ground zero out to a distance of 200 feet. Only 20 radial lines were used so as not to interfere with other experiments. A 100-foot tape was stretched between reference points along each radial line and stakes were driven at each 10-foot interval for target location.

The test objects were placed along each radial as shown by the above referenced scale drawing (Figure 2). The objects were placed in a consistent orientation on each line, but in the entire array, the cylinders, pipe, and tubing were placed (1) upright with the length vertical to the ground, (2) flat with the length perpendicular to the radial line from ground zero, and (3) flat with the length parallel to the radial line from ground zero. Throughout the remainder of the report, the orientations will be referred to as shown in Figure 3.

In addition to being placed singly, the objects were also placed in piles. The number of objects included in each stack is inclosed in parenthesis (Figure 2). Wooden blocks were stacked in pyramid fashion, beginning with a base of six blocks. Six piles were placed on two radial lines at distances of 50, 100, and 150 feet from ground zero. Three piles were oriented perpendicular and three parallel to radial lines from ground zero. An investigation of the effects of height, as well as pile configuration, on displacement was the prime reason for

this type of display. The building materials were also placed in piles 50 and 100 feet from ground zero. The bricks were stacked 50 to a pile and the 2- by-4-inch boards were stacked 30 to a pile. The arrangement of one pile of wooden blocks and lumber is shown in Figure 4.

Actual pine branches ranging in lengths from three to six feet and having trunk diameters of three to four inches were used as test objects. Poles containing four holes drilled at varying heights above the ground were used to hold the branches parallel to the ground surface which provided branch coverage from the surface of the ground to approximately 15 feet above the surface. These fabricated trees were placed on two radial lines at 50-foot intervals from ground zero. Figure 5 is a diagram of a typical fabricated tree. The pine branches, obtained a short distance north of the test site, were secured in the holes with wooden wedges, in order to simulate, as near as possible, a branch under actual circumstances. The first branches were installed four days prior to shot time. Figures 6, 7, 8, and 9 are photographs of this installation.

The Ballistic Research Laboratories (BRL), Aberdeen Proving Ground, Maryland, conducted an experiment requiring high-speed motion picture coverage (Reference 5). Added utilization of this camera was attempted by placing three steel cubes and four wooden blocks on a concrete platform level with the ground surface and in view of the high-speed camera. It was anticipated that the initial velocities, partial trajectories, and method of displacement could be derived from the film.

Unfortunately, no useful film was obtained from this endeavor.

RESULTS

An initial visual survey was made on D+1 day and the final detail survey was made after the radiation in the area had decayed to a satisfactory level. A visual search for the objects was conducted out to approximately 1,000 feet from ground zero. Each found object was surveyed and the coordinate system used to determine both preshot and postshot location. The accurace of the survey was within a minimum precision of 1 to 100. A digital computer was utilized to convert the pre- and postshot surveys to computed displacement and direction.

The detailed survey located 515 out of a total of 555 objects placed prior to the event. This is a recovery rate of 92.8 percent. Appendix A is a listing of most test items, their locations, displacements, orientations, and bearings. Since only three of the bricks and one 2-by-4-inch board were displaced, any appreciable amount and the listing of these test items would tend to be long and repetitious. Thus, the data have not been included in the tabulations.

The maximum displacement of any object was 711 feet, or a distance of 761 feet from ground zero. Twenty percent of all objects were displaced 300 feet or further from ground zero as shown graphically in Figure 10. The greatest average displacements were attained from the wooden blocks. However, a 3½-by- 6-inch cylinder (number 58) was located 675 feet from ground zero, or an actual displacement of 666 feet.

Certain results will be brought out concerning each

individual class of object. The steel plates, 1/4-by-12 inches square, had minor movement (less than four feet) in all cases except eight. These plates had displacements of from 14 to 341 feet, which are excessively high when compared with the data on the other plates, particularly those at the same distance from ground zero.

A 100-foot preshot placement of $3\frac{1}{2}$-by-9 inches cylinders placed 90 degrees apart on the north, south, east and west radial lines produced displacements of 53, 11, 1, and 195 feet when the cylinders were oriented upright, closed, open, and closed, respectively. The projected area of the open position is less than 5 percent of the upright or closed position.

None of the five wooden blocks placed less than 50 feet from ground zero were located. From 50 feet out to 200 feet, 152 blocks were placed and 91 percent were recovered. Of the recovered blocks, 20 percent were thrown farther than 420 feet from ground zero (see Figure 10). A preshot placement of piles of block 50 feet from ground zero and oriented parallel and perpendicular to the radial line from ground zero resulted in postshot maximum displacements of 459 feet and 711 feet, respectively. If we determine average displacement distances of the blocks that were in the parallel and perpendicular piles, we find that the blocks in the parallel piles had an average displacement of about 26 percent of those in the perpendicular piles. This percent closely resembles the percent of projected area avail-

able for reaction and implies somewhat the significance of projected area to missiling hazards. The blocks placed in piles had directional trajectories on the average of $\pm 15^\circ$ from the original radial line. Sixty-eight percent of these displacements were in a counter-clockwise direction.

All of the tree branches were sheared from their supports. Figures 11 and 12 show results typical of this action. Also, four of the closest supports themselves were broken off by the blast wave. Of the 32 branches placed, 75 percent were located. Three of these could not be identified, since the number plates had been lost or destroyed. The most distant branch was located 420 feet from ground zero and, although unidentifiable, it is assumed by process of elimination to have come from the closest support to ground zero, 50 feet. All branches from the 150- to 200-foot distances, as well as five of the eight branches placed at the 100-foot distance, were located and identified. At 50 feet, no branches were identifiable, although three were located without number tags. Table 2 is a compilation of the results on the tree branches. Figure 10 relates that 20 percent of all branches were displaced a distance greater than 260 feet from ground zero.

The bricks, 50 to a pile, were placed in two rows of five each and stacked five high. The amount of displacement was somewhat less than had been expected (Figures 13 and 14). Only three brick were displaced any appreciable distance and they

were recovered 243, 225, and 240 feet from ground zero. Also, the piles of lumber (2 by 4's) had minor displacement as well (Figure 15). Only one board was displaced more than seven feet from the pile and it was located 210 feet from ground zero.

Blast data for this shot were recorded by the Ballistic Research Laboratories and these records have been utilized to correlate the data in this report (Reference 1). Pertinent time and pressure values as taken from curves in the above referenced report, at distances of 40 and 200 feet respectively, ranged from (1) 840 to 17 pounds per square inch for peak overpressure, (2) 2712 to 12 psi for dynamic pressure and (3) 7 to 50 milliseconds for positive duration.

DISCUSSION

The accuracy of measurements on both the pre- and postshot surveys was within 1 in 100. This is satisfactory when judged from the point of view of the rolling and bouncing effects which are certain to have affected the direction and distance of the object displacements. In addition, under actual battlefield conditions, the initial landing of a missile would be its most likely point of damage; therefore, this would be the important governing limit. Since roll and bounce would increase the distance of the final location, it is evident that the accuracy attained is sufficient for this experiment.

To attempt an evaluation of the missile hazard from a single very low yield near-surface burst is understandably difficult. Several assumptions or areas of thought are

necessary which, because of the preliminary stage of investigation, might later be proven to have been of greater or lesser magnitudes. However, it will be attempted, at this time, using the data obtained from this one experiment, to discuss several important results which were obtained. It would appear that the greatest contributory factors toward the production of a missile is the projected area and weight of the object which is subjected to the force.

In an examination of the movement of all pipes, tubes, and cylinders, the characteristics of projected area appear to have a considerable effect on the displacement in all cases except the 3 inch cylinders, which will be discussed separately. We find that at any particular distance from ground zero, displacements for this type of object, in most instances, ranged less than 10 percent of the total movement when comparing the open position to the closed and upright positions. In general, this agrees with the projected area ratio of the open to closed position. Additionally, a look at the 3½-by- 9-inch cylinders and 4½-by-12-inch pipes shows that displacements for the open positions were generally less than five percent of the displacement for the closed and upright position; likewise, the projected areas compare similarly. From this we may assume that the projected area in a majority of cases is approximately proportionate to the total displacement when we are concerned with low yield bursts, very short duration, and other factors being identical or nearly so.

In comparing the displacements of the $3\frac{1}{2}$-by-3 inch cylinders in the open and closed or upright positions, it was discovered that in most instances, the open cylinders were displaced greater distances than the others. It would appear that this object became airborne and reached maximum velocity early in the loading phase and moved along for some distance with the blast wave front. This phenomena is attributed to the shape and light weight of this test item.

The displacement of the flat plates relates the complexities involved in this area. The gross difference in displacements from equal locations is quite evident. It is possible to have as much as 98 percent difference between minimum and maximum projected area. This difference provides an extremely variable characteristic and causes difficult forecasting and large extremes of displacement. It would be most difficult to arrive at one prediction method which would account for all variables in all forms. A review of the data on the 4-1/2-inch pipes, which weighed approximately the same as the plates, further justifies the statement of projected area being most important. The pipes in the closed and upright position had considerably more displacement, in most instances, than did the plates. However, this was not unexpected, since the pipes in this position had a much higher probability of consistent projected area.

The objects having the highest probability of consistent projected area were the wooden blocks. These objects

had the greatest amount of movement of the entire array. The displacement of the blocks placed in piles was as anticipated. That is, blocks nearest the top of the pile had greater displacements than those at the bottom. This is understandable, as the blocks on or near the top have more freedom of movement and thus are subject to becoming airborne more readily. Figures 16 and 17 show the distribution of the blocks and point out the fact that the block piles perpendicular to the ground zero line had greater displacements than those parallel to this line. This, of course, is again related basically to the amount of projected area available for the blast wave to react upon and freedom of movement. Reference 6 indicated that objects closer to the ground surface had larger displacements than those at higher elevations. However, with the piles of wooden blocks having heights of 38.5 inches, as used in this test, this was not the case. It appeared that the blast wave had a consistent effect on the piles and the blocks were displaced somewhat according to their position in the pile, the top blocks going the farthest.

The steel cubes had an average displacement less than any other test item. This is understandable, because they had the greatest weight and the ratio of projected area to mass was the least of any of the test items.

It is impossible to give a logical explanation why three bricks, from the two piles of 50 each, were displaced

225, 240, and 243 feet, while the remaining brick moved very little. Nor can the 210-foot displacement of a single 2- by-4-inch board, from one of the two stacks of 30 each, be satisfactorily explained.

The direction of displacement is, of course, most important because it is the basic measurement for safe distance. Figure 18 is a diagram of the directional vectors of all objects, except tree branches, stacked 2- by-4 lumber, stacked brick, and 5-1/2-inch wooden blocks in piles. A study of this figure shows the random scatter of the objects.

The data discloses that the objects in the eastern half of the array had considerably less movement than those in the western half. It is believed that this was caused, to a certain extent, by the breakup of the blast wave when it contacted the military tanks present in this area. Figures 19 and 20 are photographs taken of this area, and it can be seen that the test items are still in relatively straight lines and have fairly even spacing.

The data show that at a distance of 145 feet from ground zero, 73 percent of the ideal objects would be casualty-producing missiles. At the same distance, the overpressure was 35 psi (Reference 1), which has a 1.0 percent probability of human fatality (Reference 10). At a distance of 700 feet from ground zero, the overpressure dissipated to two psi (Reference 1) and the missile hazard was reduced to 0.4 percent probability. However, the initial radiation at 700 feet from ground zero for a burst of this type is approximately 3,000 rem (References 3 and 4), which is well

above the probable survival level for whole-body radiation. All recovered objects were displaced less than 1,000 feet; however, the initial radiation at this distance was 1,000 rem. This shows that the initial radiation is the most far-reaching effect measured as horizontal distance from ground zero. The simple foxhole would reduce the radiation effect but it is felt that this type of protection would not reduce the missile effect radius any appreciable amount; however, additional study and investigations should be conducted to establish the parameters of foxhole protection.

Probably the most significant result obtained from this test was the displacement of the tree branches, especially those along the 30-degree radial line where the branches had freedom of movement and no obstructions in their flight path. Of the sixteen branches emplaced, eleven were recovered and identified, all having a preshot location of 100, 150, and 200 feet from ground zero. Six of the eleven branches were displaced a distance of 259 feet (plus or minus 18 feet) from ground zero (Figures 21 and 22). This pile-up of branches was probably caused by the decay of the initial impulse and wind velocity at a rate proportionate to the distance offset of the trees. The branches along the 300 degree radial line did not displace as far from ground zero as those on the 30-degree radial line; however, the ground surface had a slight incline, 180 to 210 feet from ground zero, and half the identified branches were found on

this slope. This would seem to indicate that similar results could have been expected had the ground been level. The above discussion is not in agreement with the theoretical estimate of the debris hazards to troops by flying tree limbs in the proximity of forest stands, as found in Reference 9.

An evaluation of the displacement of all test objects shows that less than 12 percent of the objects had been displaced more than 350 feet from ground zero. Also, it was revealed that less than 5 percent of the ideal test objects placed directly upon the ground surface were displaced beyond this distance. Upon further analysis of the data, it was noted that relatively few objects, with a preshot placement of 150 feet or more from ground zero, had displacements greater than 20 feet and most of these were stacked wooden blocks.

CONCLUSIONS

It is concluded:

(1) The effective distance at which missiles would produce a serious hazard to field personnel is less than 350 feet from a burst of this type.

(2) That no consistent pattern of direction can be established and missiles can be expected to have a directional angle ranging up to plus or minus 30 degrees from their initial location.

(3) That small objects, such as those used in this experiment, on the surface of the ground, 150 feet or more from a burst of this type, should not pose a serious missile hazard.

(4) Projected area is a more important factor than

anticipated and appears to be a prime factor in establishing criteria for missile production.

(5) Nuclear radiation is the governing casualty-producing factor for exposed troops.

(6) A low yield burst of this type in a sparsely forested area would form a barrier of branches at some undetermined distance from ground zero.

(7) Additional study and experiments are required to more thoroughly understand the behavior of missiles created by very low-yield nuclear bursts.

TABLE 1. TABULATION OF TEST OBJECTS

Item	Objects	Dimension	Quantity	Average Weight	
		inches		pounds	ounces
1	Steel Cylinders	3-1/2 OD x 3 long-1/4 thick	30	1	15
2	Steel Cylinders	3-1/2 OD x 6 long-1/4 thick	40	3	12
3	Steel Cylinders	3-1/2 OD x 9 long-1/4 thick	44	5	10
4	Steel Cubes	4 x 4 x 3-1/2 long	34	16	0
5	Steel Pipes	4-1/2 OD x 12 long	30	10	6
6	Steel Tubes	3 SQ x 12 long	30	6	13
7	Steel Plates	12 x 12 x 1/4	30	10	6
8	Wooden Boards	2 x 4 x 72 long	60	--	--
9	Wooden Blocks	5-1/2 x 5-1/2 x 5-1/2	157	3	3
10	Bricks	3-7/8 x 2-1/2 x 8-1/4	100	--	--
	TOTAL (Ideal Objects) ----------------------------------		555		
11	Tree Limbs	36-72 long x 3-4 trunk diameter	32		
	TOTAL (All Test Objects)----------------------------------		587		

TABLE 2. TABULATION OF TREE BRANCH DISPLACEMENT DATA

	Preshot			Postshot				
No.	Distance From GZ ft	Bearing From GZ	Height Above Ground in.	Distance From GZ ft	Displacement ft	Bearing From Pre-Shot Position	Perpendicular Distance[a] ft	Bearing From GZ
Tree Limb								
11[b]	50	N60W	30	--	--	--	--	--
12[b]		N60W	65	--	--	--	--	--
13[b]		N60W	100	--	--	--	--	--
14[b]		N60W	135	--	--	--	--	--
51[b]		N30E	35	--	--	--	--	--
52[b]		N30E	70	--	--	--	--	--
53[b]		N30E	105	--	--	--	--	--
54[b]		N30E	140	--	--	--	--	--
21	100	N60W	45	194.9	92.25	N63.4W	11.7	N67W
22[b]		N60W	80	--	--	--	--	--
24[b]		N60W	150	--	--	--	--	--
61[b]		N30E	21	--	--	--	--	--
62		N30E	56	181.6	83.5	N13.5E	23.7	N22.4E
63		N30E	91	257.38	157.5	N33.4E	9.6	N32.1E
23		N60W	115	161.6	64.0	N41.7W	21.0	N52.5W
64		N30E	126	275.2	178.2	N12.3E	54.0	N18.6E
31	150	N60W	34	176.1	26.2	N56.7W	1.5	N59.5W
32		N60W	69	192.4	42.7	N53.8W	4.6	N58.7W
33		N60W	104	189.9	40.0	N61.9W	1.3	N60.4W
34		N60W	139	204.1	55.8	N43.8W	15.6	N55.6W
71		N30E	60	215.3	65.1	N28.6E	1.9	N29.8E
72		N30E	95	209.38	59.2	N28.4E	2.0	N29.8E
73		N30E	130	247.3	97.5	N24.3E	10.2	N28E

TABLE 2. TABULATION OF TREE BRANCH DISPLACEMENT DATA (CONTINUED)

	Preshot			Postshot				
No.	Distance From GZ	Bearing From GZ	Height Above Ground	Distance From GZ	Displacement	Bearing From Pre-Shot Position	Perpendicular Distance[a]	Bearing From GZ
	ft		in	ft	ft		ft	
74	150	N30E	165	251.1	101.1	N35E	8.2	N32.2E
41	200	N60W	47	238.5	39.1	N76W	10.6	N62.7W
42		N60W	82	219.6	40.6	N7.1E	37.5	N50.3W
43		N60W	117	287.6	87.6	N68.7W	13.0	N62.8W
44		N60W	152	269.0	68.4	N58W	2.5	N59.4W
81		N30E	57	248.2	48.3	N23.2E	5.6	N28.6E
82		N30E	92	254.9	54.8	N28.8E	1.1	N29.6E
83		N30E	127	253.6	53.6	N24.9E	4.6	N28.8E
84		N30E	162	242.4	49.9	N65.4E	29.0	N36.8E
A[c]		N60W	---	420.0	---	---	1.8	N59.8W
B[c]		N60W	---	313.5	---	---	23.1	N55.8W
C[c]		N30E	---	159.1	---	---	13.6	N25.1E

[a] Measurement made perpendicular from original radial line to terminal location.
[b] These branches could not be located.
[c] Lettered branches could not be identified as number tags had been destroyed.

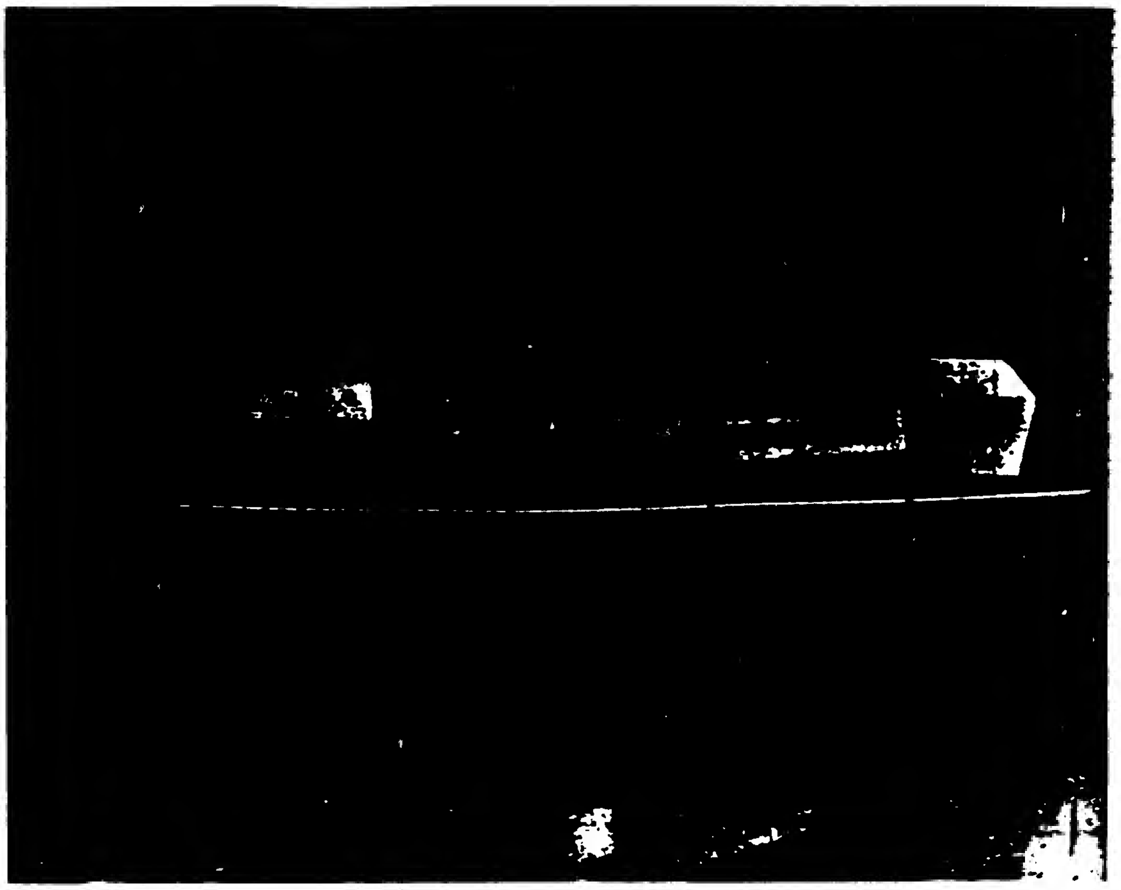


Figure 1 Typical ideal objects: 4-by-12 pipe, 3-by-3 cylinder, $4\frac{1}{2}$ cube, [illegible]-by-6 cylinder, 4-by-12 tube, $5\frac{1}{2}$ wood block. (DASA-[illegible]-NTS-62)

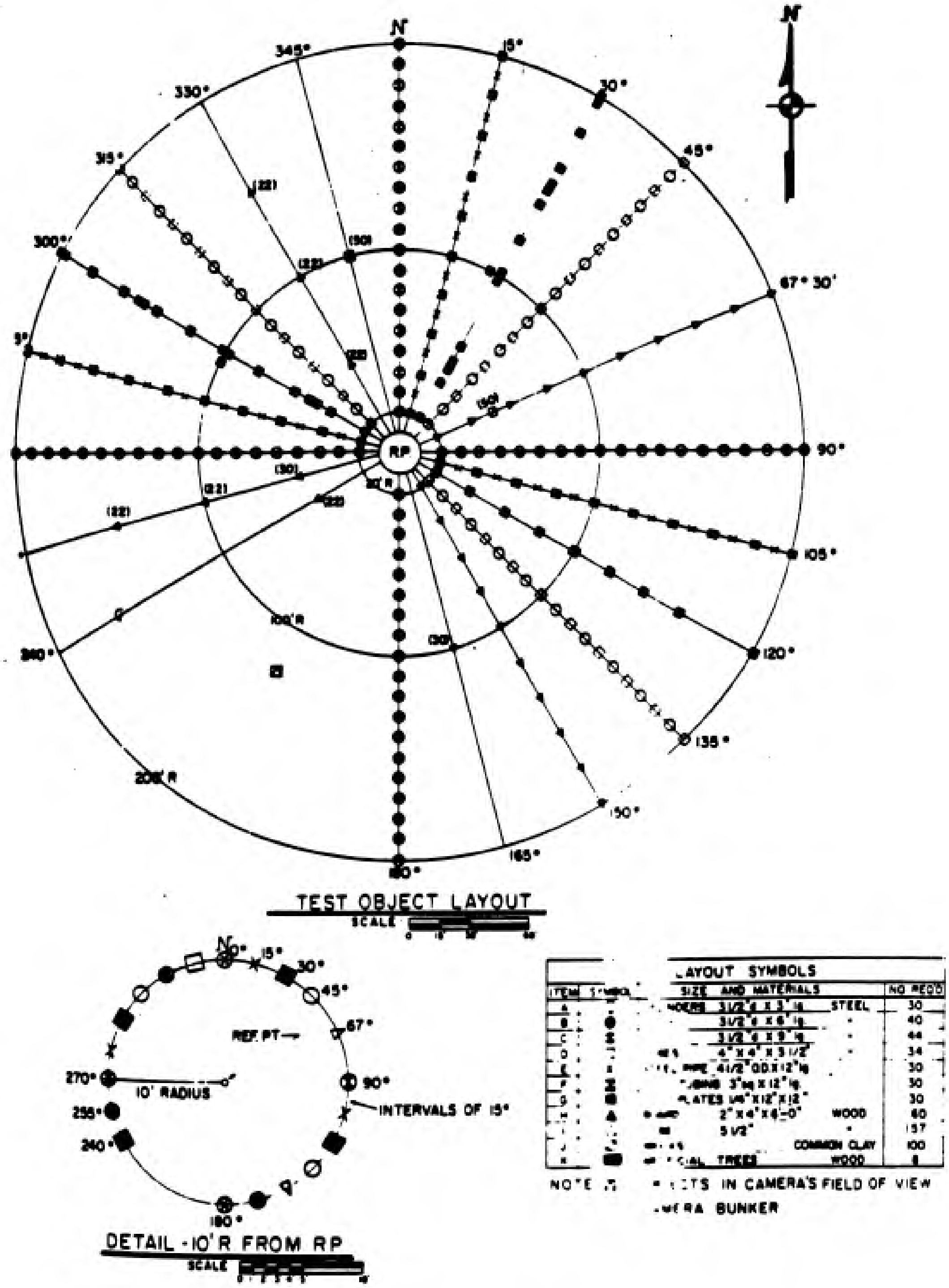


Figure 2 Test object layout.

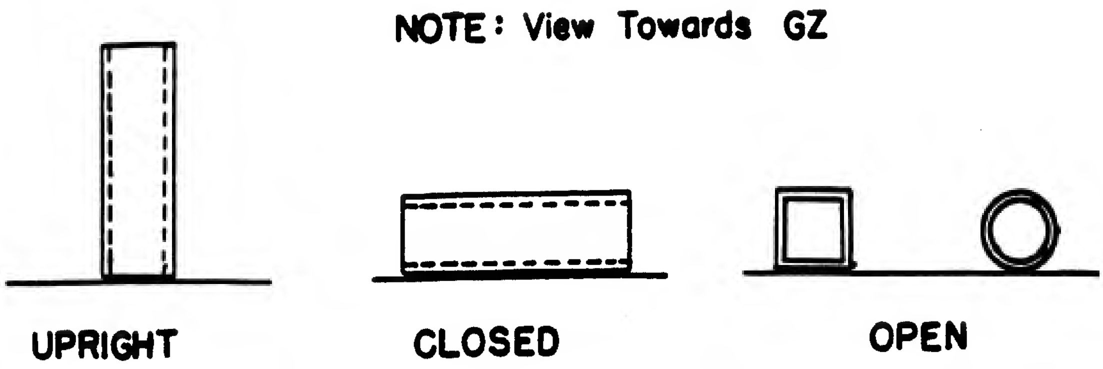
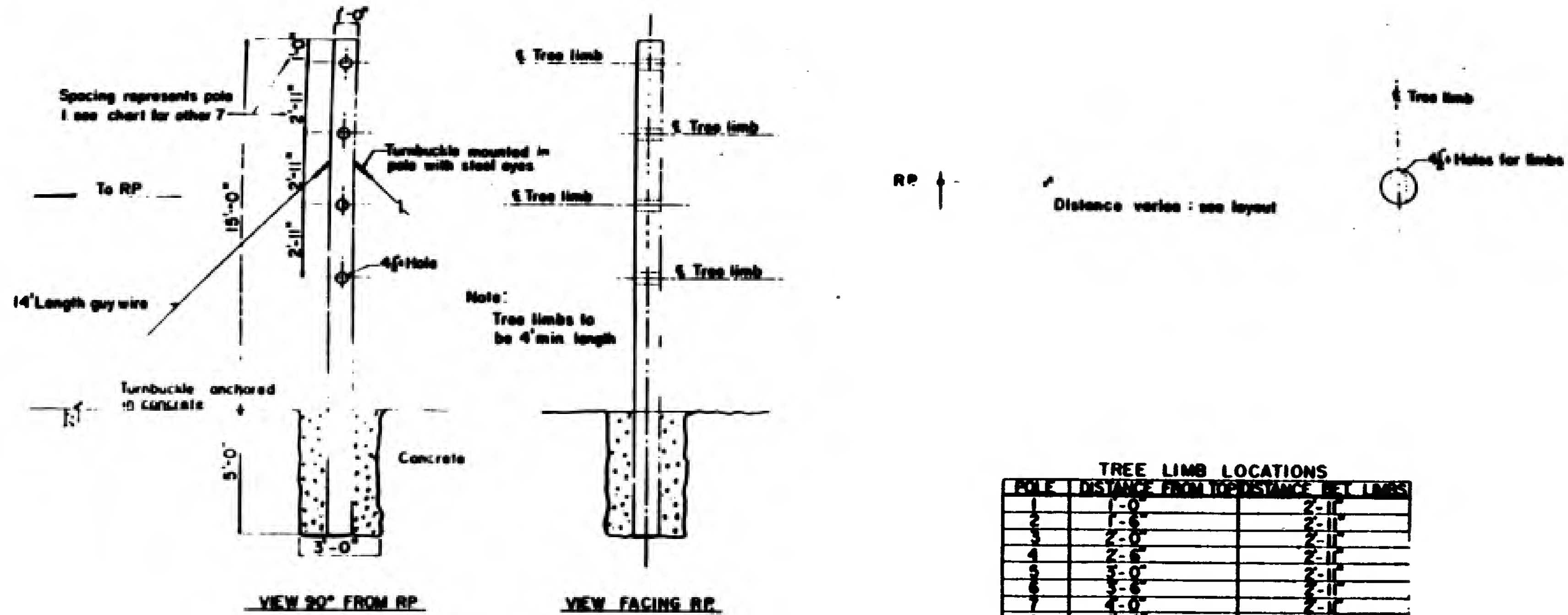


Figure 3 Orientation nomenclature for objects.

[illegible]re 4 Wood blocks (1) and 2-by-4 boards (2) [illegible]les. (DASA-725-07-NTS-62)



TREE LIMB LOCATIONS

POLE	DISTANCE FROM TOP	DISTANCE BET. LIMBS
1	1'-0"	2'-11"
2	1'-6"	2'-11"
3	2'-0"	2'-11"
4	2'-6"	2'-11"
5	3'-0"	2'-11"
6	3'-6"	2'-11"
7	4'-0"	2'-11"
8	4'-6"	2'-11"

Figure 5 Tree branch exposure technique.

Figure 6 Typical installation of tree branches at 50 and 100 feet from ground zero, N30E line. (DASA-725-06-NTS-62)

Figure 7 Typical installation of tree branches at 150 and 200 feet from ground zero, N30E line. (DASA-725-01-NTS-62)

Figure 8 Typical installation of tree branches at 50 and 100 feet from ground zero, N60W line. (DASA-725-04-NTS-62)

Figure 9 Typical installation of tree branches at 150 and 200 feet from ground zero, N60W line. (DASA-725-05-NTS-62)

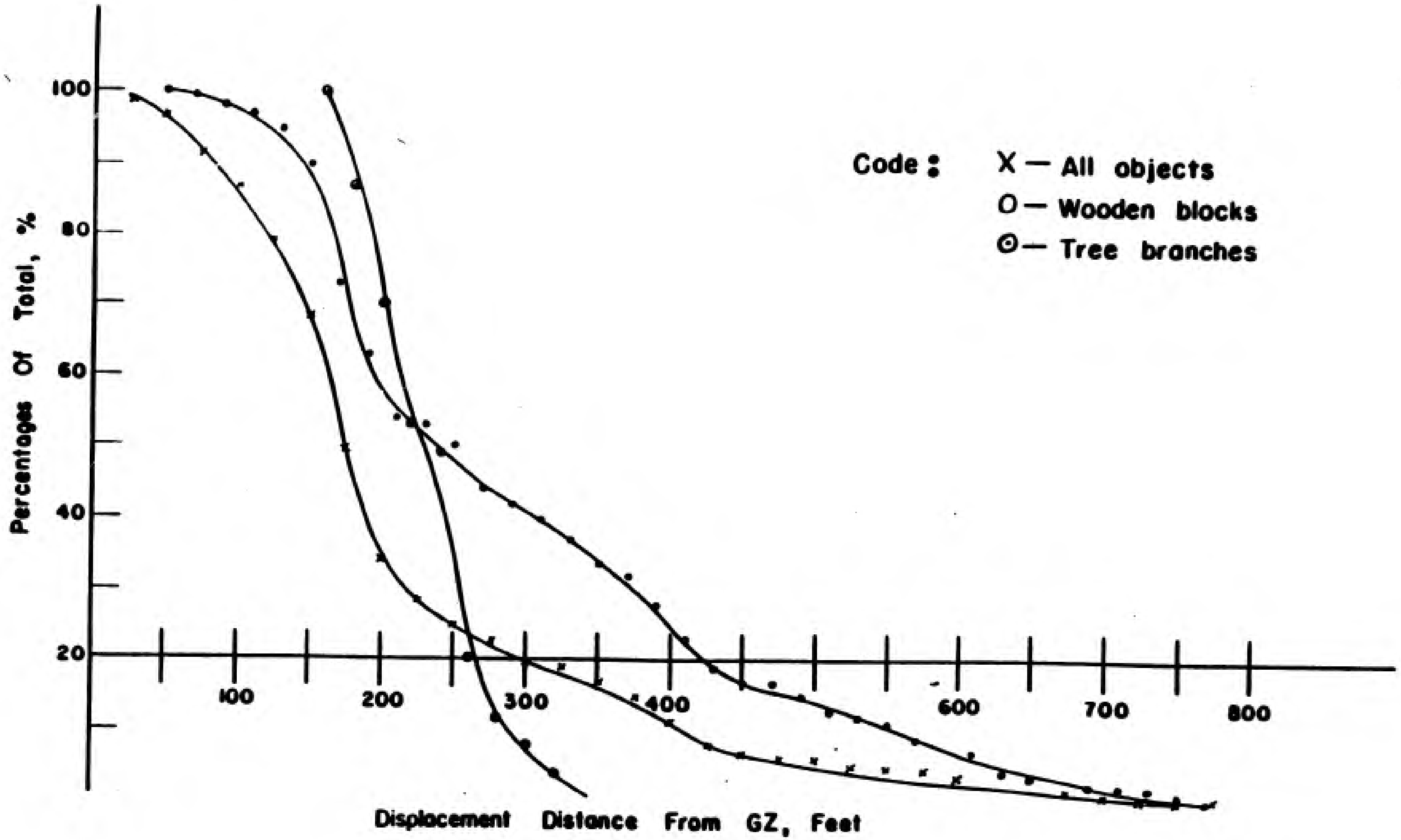


Figure 10 Cumulative percents of displacement for objects.

Figure 10 Cumulative percents of displacement for objects.

Figure 11 Tree branches, postshot, N30E line. (USAERDL J10065)

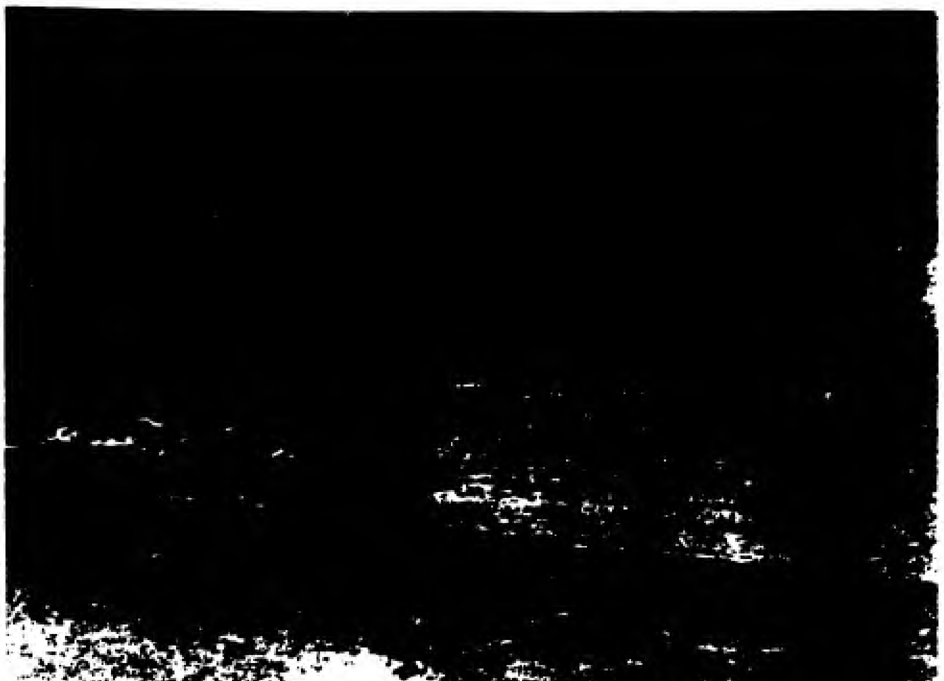


Figure 12 Tree branches, postshot, N60W line. (USAERDL J10061)

Figure 13 Brick pile, postshot, N67-30E line.
(USAERDL J10068)

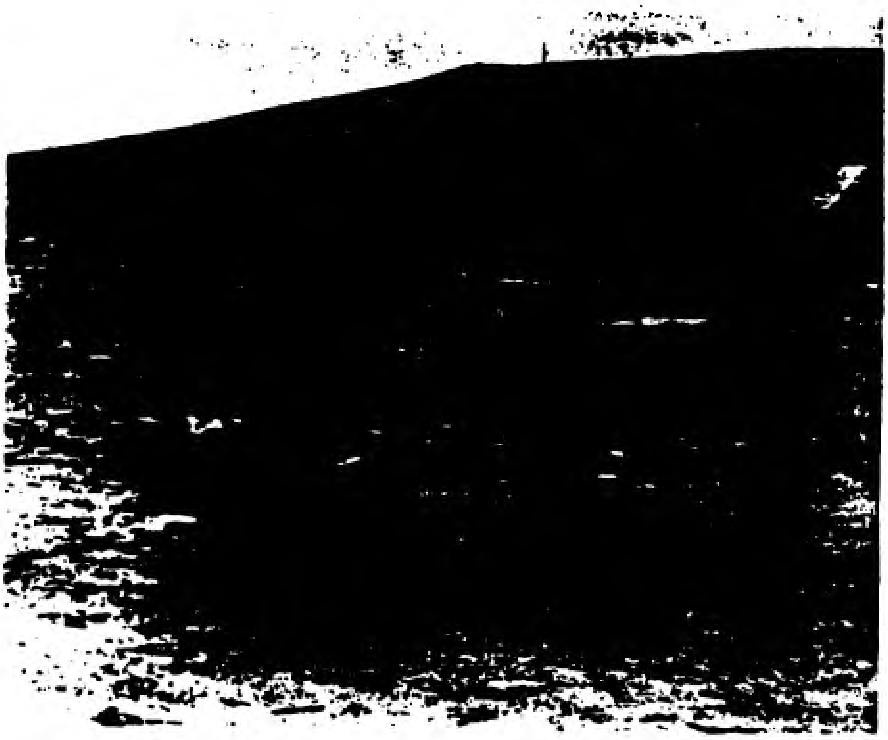


Figure 14 Brick pile, postshot, N67-30E line.
(USAERDL J-9452)

Figure 15 2-by-4 boards in pile, postshot, S15E line. (USAERDL J-9456)

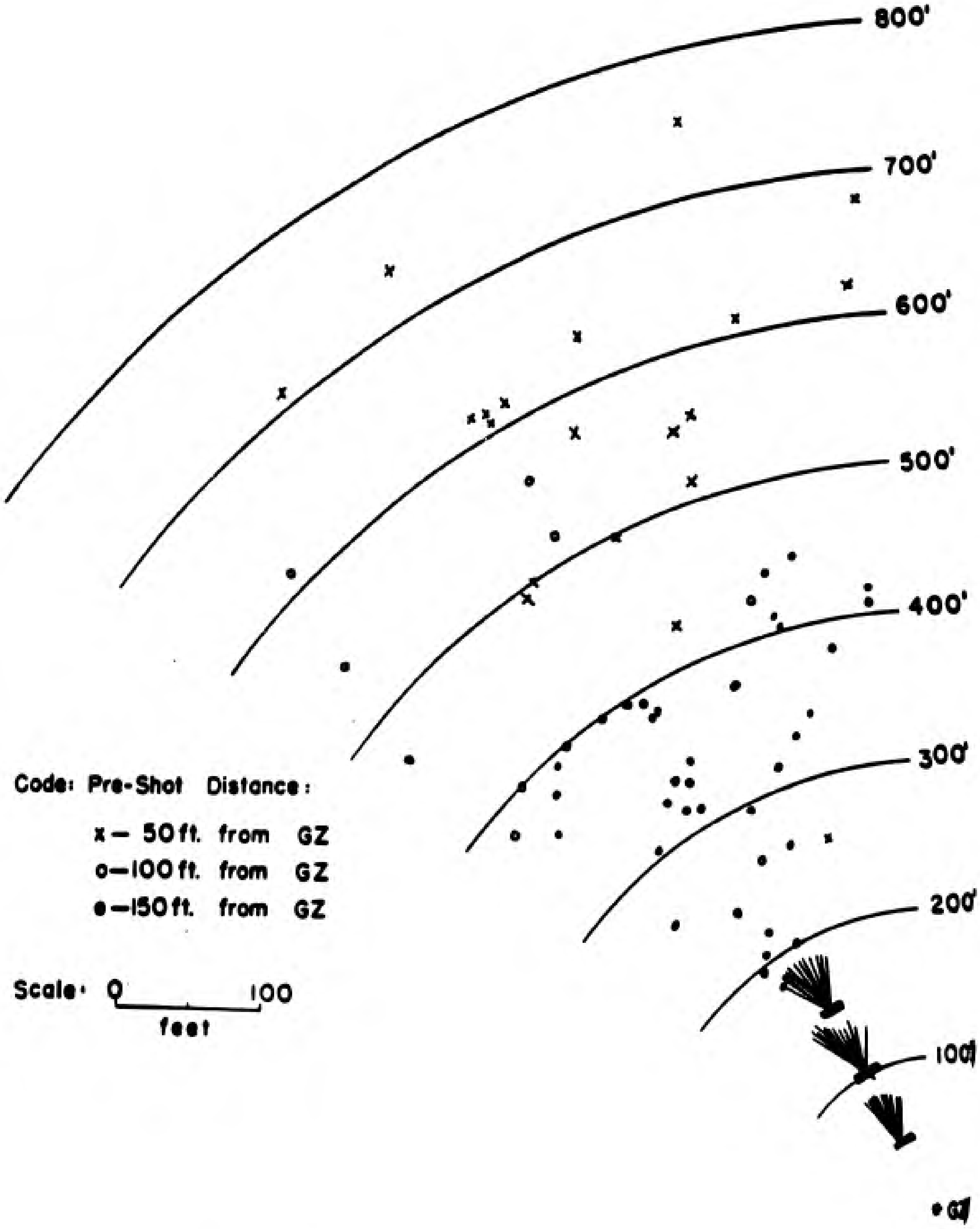


Figure 16 Wood blocks on N30W line (perpendicular pile).

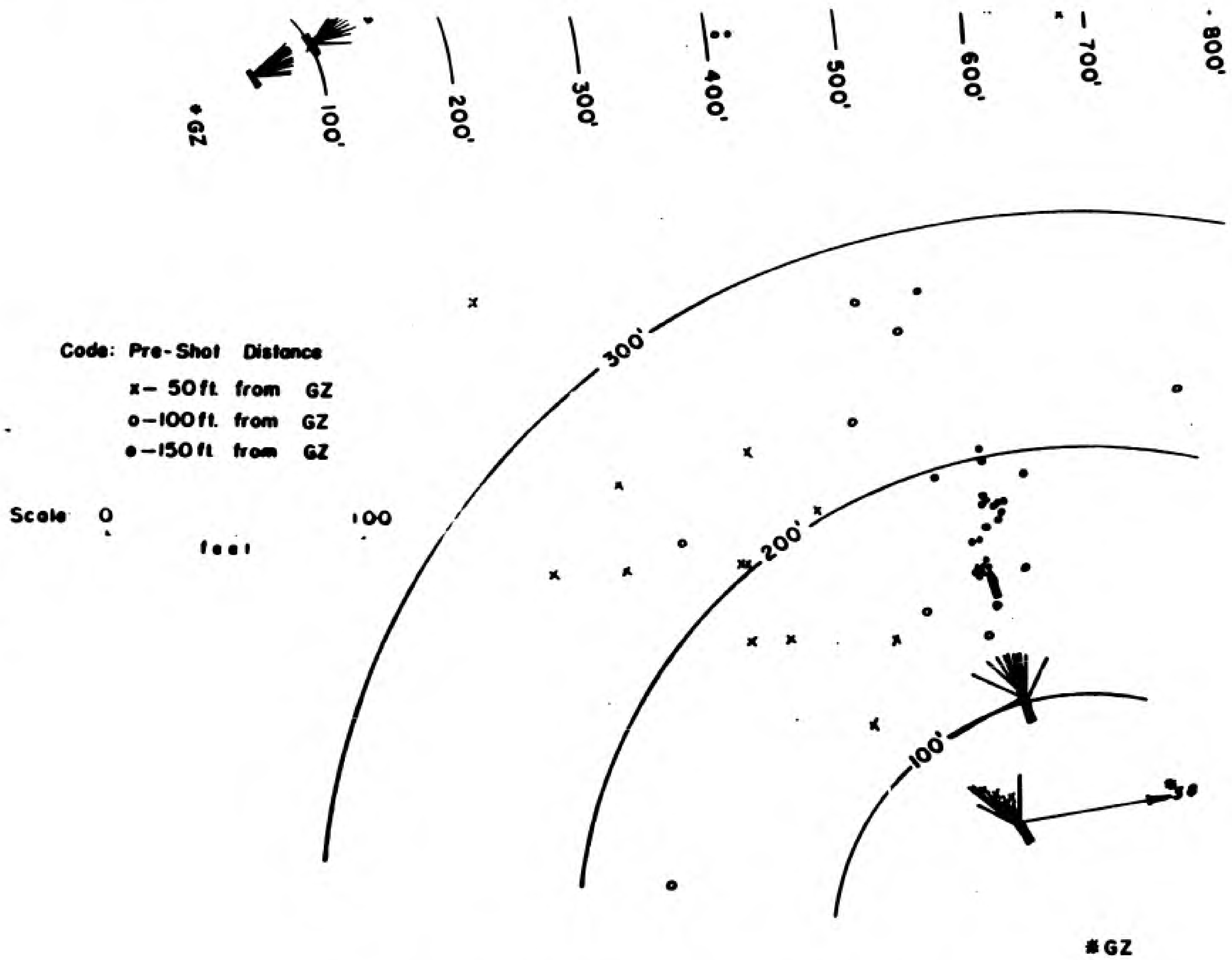


Figure 17 Wood blocks on S60W line and S75W line (parallel pile).

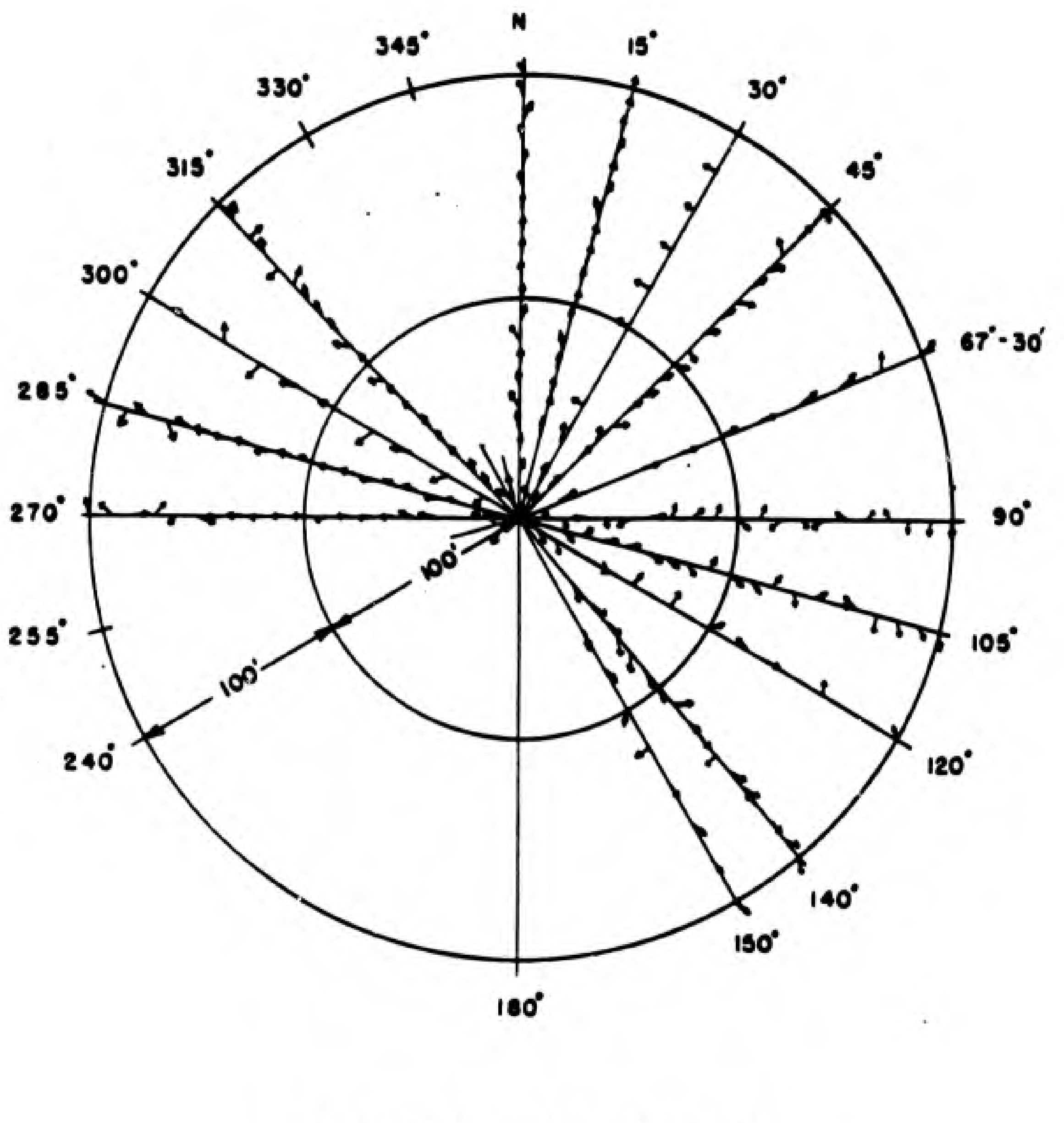


Figure 18 Directional vectors of objects.

Figure 19 Cylinders, postshot, S45E line. (USAERDL J-9455)

Figure 20 Wooden blocks, N67° 30' E line. (USAERDL J-9451)

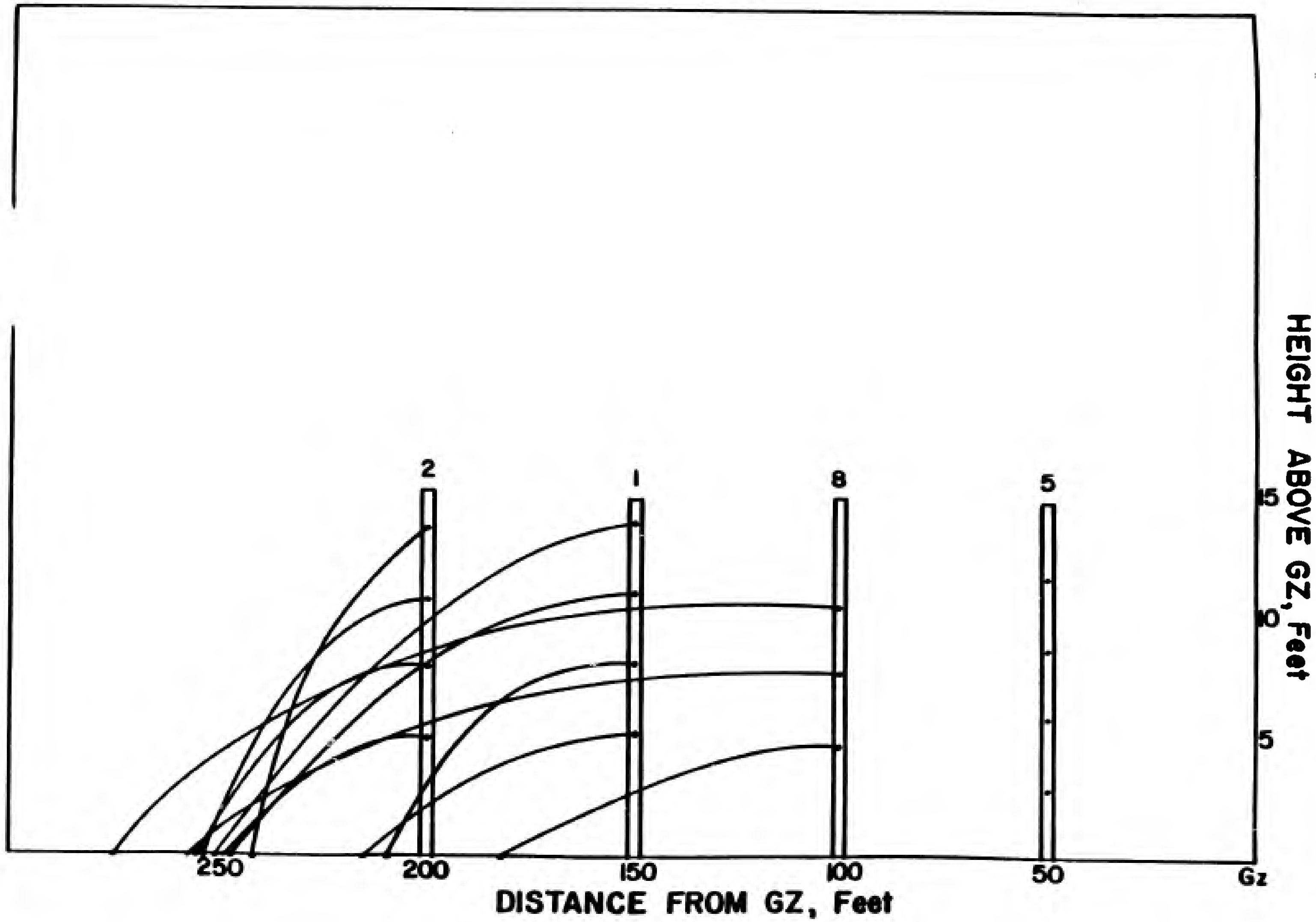


Figure 21 Tree limb displacement, 30-degree line.

150 100 50 Gz

DISTANCE FROM GZ, Feet

Figure 21 Tree limb displacement, 30-degree line.

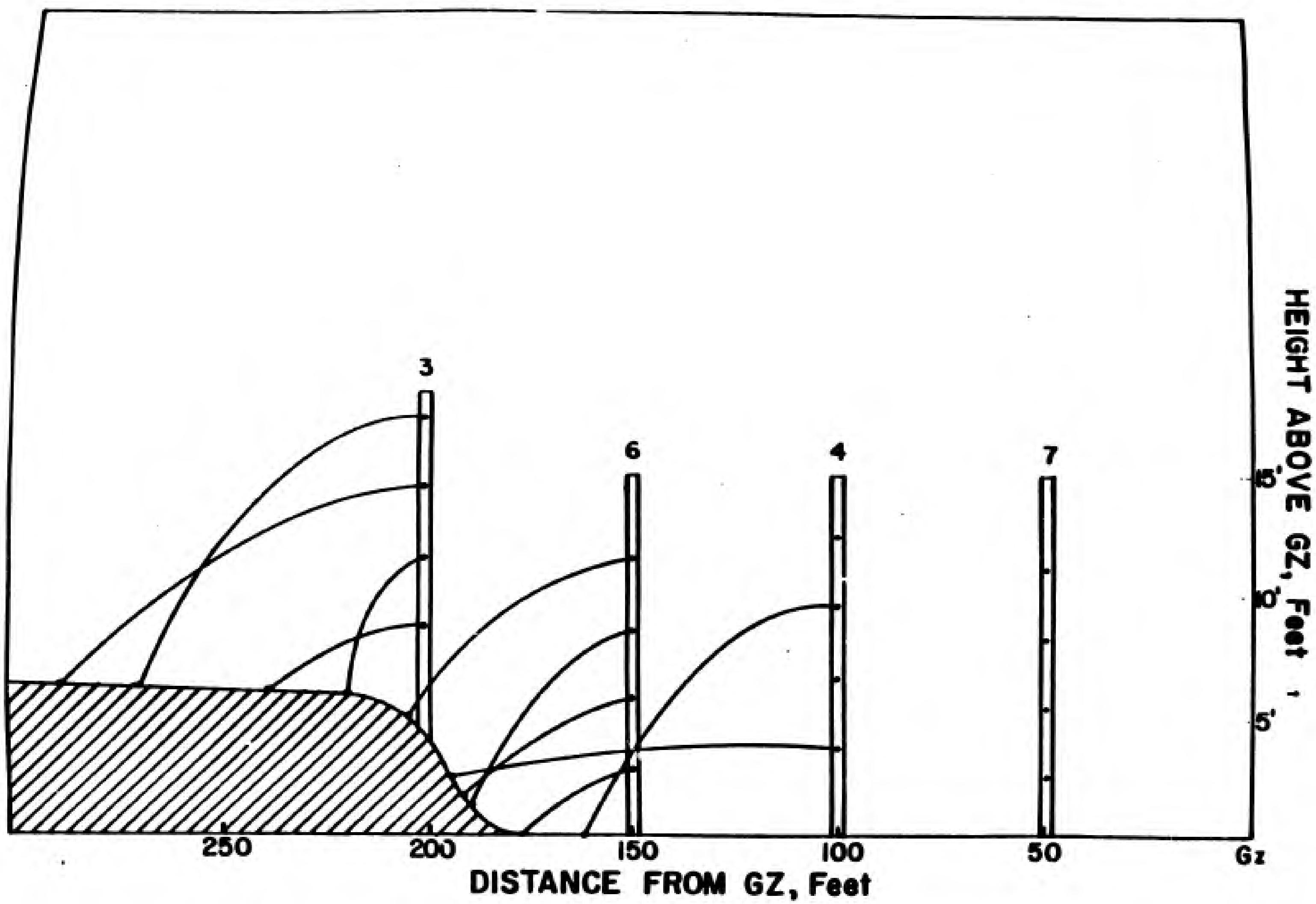


Figure 22 Tree limb displacement, 300-degree line.

APPENDIX A

DATA TABULATIONS

TABLE A.1 TABULATION OF ALL IDEAL OBJECTS DISPLACEMENT DATA

	Preshot			Postshot				
No.	Distance From GZ ft	Bearing From GZ	Orientation	Distance From GZ ft	Displacement ft	Bearing From Pre-Shot Position	Perpendicular Distance[a] ft	Bearing From GZ
3 1/2" x 3" Long Cylinder								
7	10	N45E	Open	581.0	572.8	N10.1E	327.8	N10.7E
3	10	S40E	Closed	Not Located				
22	10	N45W	Upright	Not Located				
29	30	N45E	Upright	Not Located				
26	30	N45W	Open	91.3	65.9	N6.8W	40.8	N18.5W
23	30	S40E	Closed	Not Located				
10	50	N45E	Open	51.2	1.4	N17.1E	0.8	N44.2E
11	50	S40E	Open	89.1	40.0	S56.2E	11.2	S47.2E
30	50	N45W	Closed	196.6	146.7	N43.4W	4.21	N43.8W
1	70	N45E	Closed	134.9	64.9	N43.9E	1.3	N44.5E
12	70	S40E	Upright	81.3	12.1	S18.5E	4.4	S36.9E
5	70	N45W	Open	186.0	116.1	N49.8W	9.6	N47.9W
8	90	N45E	Upright	94.0	4.5	N65.7E	1.9	N46.1E
4	90	S40E	Closed	135.7	45.8	S34.9E	4.1	S38.3E
19	90	N45W	Open	136.4	53.3	N81.9W	32.0	N58.6W
16	110	N45E	Open	109.8	0.8	S31.3E	0.8	N45.4E
27	110	S40E	Open	110.3	0.7	N76.4E	0.7	S40.3E
28	110	N45W	Closed	145.8	44.0	N86.6W	29.2	N56.6W
18	130	N45E	Closed	134.0	4.1	N50.3E	0.4	N45.2E
6	130	S40E	Upright	147.C	17.6	S38.9E	0.3	S39.9E
25	130	N45W	Open	188.6	60.5	N27.9W	17.8	N39.6W
20	150	N45E	Upright	150.5	0.6	N64.3E	0.2	N45.1E
24	150	S40E	Closed	150.2	0.2	S7.7E	0.1	S39.9E
15	150	N45W	Open	152.4	5.8	N21.4E	5.3	N41W
2	170	N45E	Open	170.3	0.4	N1.2W	0.3	N45.1E
13	170	S40E	Open	167.7	2.3	N29.3W	0.4	S39.9E
14	170	N45W	Upright	171.8	2.2	N9.8W	1.3	N44.6W
21	190	N45E	Closed	191.2	1.3	N51.5E	0.1	N45E
9	190	S40E	Upright	190.6	0.8	S67.1E	0.4	S40.1E
17	190	N45W	Open	190.6	1.8	S65W	1.7	N44.5W
3 1/2" x 6" Long Cylinder								
46	10	S75W	Open	181.0	175.7	N45.7W	151.2	N48.4W
35	10	S15E	Upright	Not Located				
58	10	N30W	Closed	674.9	665.8	N55.1W	282.4	N54.7W
65	20	N67.5E	Open	27.6	7.8	N52.3E	2.0	N63.3E
51	30	North	Upright	390.0	360.1	N1E	6.9	N1E
34	30	N90E	Open	9.5	20.6	S87.6W	0.9	S84.5E
62	30	South	Closed	Not Located				

TABLE A.1 Continued

	Preshot			Postshot				
No.	Distance From GZ ft	Bearing From GZ	Orientation	Distance From GZ ft	Displacement ft	Bearing From Pre-Shot Position	Perpendicular Distance[a] ft	Bearing From GZ
40	30	N90W	Closed	Not Located				
36	50	North	Upright	180.1	132.7	N21.7W	49.1	N15.8W
42	50	N90E	Open	50.6	2.4	S66.6W	2.3	S87.4W
50	50	South	Closed	255.1	205.1	S1.8W	6.6	S1.5W
48	50	N90W	Closed	403.3	354.1	N79.4W	65.3	N80.7W
66	70	North	Upright	183.8	113.9	N0.9E	1.8	N0.6E
43	70	N90E	Open	75.9	9.3	N36.6E	7.5	N84.4E
60	70	South	Closed	151.1	81.2	S4.1E	5.8	S2.2E
61	70	N90W	Closed	351.0	281.0	N88.8W	5.9	N89W
38	90	North	Upright	Not Located				
64	90	N90E	Open	96.8	12.2	N40.8E	10.5	N83.8E
44	90	South	Closed	100.7	10.8	S6.2W	1.2	S0.7W
67	90	N90W	Closed	216.6	126.8	S84.7W	11.8	S86.9W
47	110	North	Upright	192.4	82.5	N1.4W	2.1	N0.6W
53	110	N90E	Open	110.3	0.5	N39.2E	0.4	N89.8E
59	110	South	Closed	113.4	3.4	S5.2E	0.3	S0.2E
57	110	N90W	Closed	225.3	115.5	N85.2W	9.7	N87.5W
63	130	North	Upright	143.7	13.8	N3.5E	0.8	N0.3E
32	130	N90E	Open	130.1	0.5	S31.3E	0.5	S89.8E
70	130	South	Closed	138.0	8.1	S7.9E	1.1	S0.7E
49	130	N90W	Closed	175.0	45.1	N89.4W	0.5	N89.9W
52	150	North	Upright	153.6	3.6	N2.4W	0.2	N0.1W
39	150	N90E	Open	149.7	0.4	S48W	0.3	S89.9E
6[illegible]	150	South	Closed	155.0	5.0	S0.3W	0.0	South
55	150	N90W	Closed	144.1	6.0	N78.3E	1.2	N89.5W
33	170	North	Upright	173.4	3.5	N5.1W	0.3	N0.1W
31	170	N90E	Open	169.8	0.1	S78.7W	0.0	S89.9E
54	170	South	Closed	173.1	3.2	S5.5W	0.3	S0.1W
68	170	N90W	Closed	164.9	6.7	S50.2E	4.3	S88.5W
37	190	North	Upright	191.6	1.7	N7.7W	0.2	N0.1W
45	190	N90E	Open	189.8	0.6	S17.2W	0.6	S89.8E
56	190	South	Closed	190.9	1.4	S42.3W	0.9	S0.3W
69	190	N90W	Closed	190.9	1.3	N53W	0.8	N89.8W
3 1/2" x 9" Long Cylinder								
110	10	North	Upright	Not Located				
97	10	N90E	Open	58.3	52.6	N30.5E	45.3	N39E
112	10	South	Closed	Not Located				
101	10	N90W	Closed	Not Located				
100	20	North	Upright	328.8	307.2	N12E	64.0	N11.3E

TABLE A.1 Continued

Preshot				Postshot				
No.	Distance From GZ ft	Bearing From GZ	Orientation	Distance From GZ ft	Displacement ft	Bearing From Pre-Shot Position	Perpendicular Distance[a] ft	Bearing From GZ
113	20	N90E	Open	202.1	189.5	S36.8E	151.8	S31.3E
95	20	South	Closed	Not Located				
109	20	N90W	Closed	Not Located				
75	40	North	Upright	298.3	258.5	N5.1W	23.1	N4.4W
83	40	N90E	Open	40.8	2.3	S18.4E	2.2	S87E
92	40	South	Closed	282.1	242.3	S5E	21.2	S4.3E
73	40	N90W	Closed	381.2	341.4	N84.5W	32.5	N85.1W
80	60	North	Upright	225.6	165.7	N4W	11.6	N3W
85	60	N90E	Open	63.4	3.4	N84E	0.4	N89.7E
114	60	South	Closed	114.5	54.6	S1.8W	1.7	S0.9W
89	60	N90W	Closed	276.4	216.5	N87.5W	9.6	N88W
72	80	North	Upright	Not Located				
74	80	N90E	Open	83.3	3.7	N65.5E	1.5	N89E
81	80	South	Closed	189.5	109.6	S3.1E	5.8	S1.8E
71	80	N90W	Closed	247.9	168.1	S85.3W	13.7	S86.8W
105	100	North	Upright	153.2	53.3	N2.1E	1.9	N0.7E
96	100	N90E	Open	100.1	0.7	S35.1E	0.6	S89.6E
78	100	South	Closed	111.0	11.0	S4.2W	0.8	S0.4W
87	100	N90W	Closed	294.4	194.6	N86.4W	12.1	N87.6W
106	120	North	Upright	132.8	12.8	N0.9E	0.2	N0.1E
86	120	N90E	Open	104.9	15.4	S59.9W	2.7	S88.5E
76	120	South	Closed	137.6	17.7	S4.9W	1.5	S0.6W
107	120	N90W	Closed	166.7	47.7	N88.3W	1.4	S89.5W
94	140	North	Upright	147.9	7.9	North	0.0	North
111	140	N90E	Open	139.9	0.1	S45W	0.1	S89.9E
93	140	South	Closed	152.0	12.1	S2.8W	0.6	S0.2W
91	140	N90W	Closed	201.3	61.4	S87.3W	3.0	S89.2W
84	160	North	Upright	166.3	6.4	N6.2E	0.7	N0.2E
82	160	N90E	Open	160.0	0.1	N42E	0.1	N89E
104	160	South	Closed	164.4	4.6	S11.7W	0.9	S0.3W
103	160	N90W	Closed	168.0	9.7	S57.1W	5.5	S88.1W
88	180	North	Upright	181.3	1.5	N21.8E	0.6	N0.2E
77	180	N90E	Open	179.8	0.3	S19.7W	0.3	S89.9E
98	180	South	Closed	184.3	4.4	S6.7W	0.5	S0.2W
79	180	N90W	Closed	179.3	0.6	N88.1E	0.0	N89.9W
90	200	North	Upright	200.6	0.7	N4.9W	0.1	N0.1W
108	200	N90E	Open	199.9	0.5	South	0.5	S89.9W
102	200	South	Closed	201.9	2.2	S25.1W	0.9	S0.3W
99	200	N90W	Closed	200.0	0.6	N9.3W	0.6	N89.8W
4 1/2" x 12" Long Pipe								
13	10	N15E	Closed	Not Located				

TABLE A.1 Continued

	Preshot			Postshot				
No.	Distance From GZ ft	Bearing From GZ	Orientation	Distance From GZ ft	Displacement ft	Bearing From Pre-Shot Position	Perpendicular Distance[a] ft	Bearing From GZ
3	10	S75E	Open	Not Located				
19	10	N75W	Upright	Not Located				
15	30	N15E	Closed	Not Located				
20	30	S75E	Open	33.1	3.6	N72.3E	2.0	S78.4E
10	30	N75W	Upright	419.3	289.4	N70.5W	30.3	N79.2W
2	50	N15E	Closed	288.4	238.4	N15.8E	3.5	N15.7E
16	50	S75E	Open	51.0	1.1	S54.2E	0.4	S74.6E
28	50	N75W	Upright	160.2	110.4	N68.6W	12.3	N79.4W
11	70	N15E	Closed	282.7	212.9	N10.1E	18.1	N11.3E
5	70	S75E	Open	70.7	1.1	S21.2E	0.9	S74.3E
12	70	N75W	Upright	209.5	139.9	N82W	17.1	N79.7W
27	90	N15E	Closed	108.9	19.0	N13.4E	0.5	N14.8E
6	90	S75E	Open	91.2	3.4	N34.4E	3.2	S77E
23	90	N75W	Upright	176.2	86.3	N75.3W	0.4	N75.1W
24	110	N15E	Closed	130.6	20.7	N13.8E	0.4	N14.8E
22	110	S75E	Open	110.4	0.6	S33.2E	0.4	S74.8E
9	110	N75W	Upright	189.2	79.7	N66.5W	11.7	N71.5W
8	130	N15E	Closed	157.6	27.6	N16.6E	0.8	N15.3E
26	130	S75E	Open	130.1	0.6	S5.4W	0.6	S74.7E
29	130	N75W	Upright	149.9	19.9	N74.6W	0.1	N74.9W
17	150	N15E	Closed	167.6	17.7	N20.1E	1.6	N15.5E
14	150	S75E	Open	150.1	0.2	S74E	0.0	S75E
1	150	N75W	Upright	163.0	13.1	N75.8W	0.2	N75.1W
7	170	N15E	Closed	178.3	8.5	N25.1E	1.5	N15.5E
4	170	S75E	Open	170.0	0.6	S5.9W	0.6	S74.8E
21	170	N75W	Upright	154.0	114.1	S12.9E	100.8	S64.1W[b]
30	190	N15E	Closed	193.5	3.6	N14E	0.1	N15E
25	190	S75E	Open	190.3	0.6	S23.9E	0.5	S74.9E
18	190	N75W	Upright	190.0	0.3	S32W	0.3	N75.1W
3" Square x 12" Long Tube								
7	20	N15E	Closed	Not Located				
30	20	S75E	Open	Not Located				
2	20	N75W	Upright	107.2	88.7	S80.3W	27.1	S84.8W
13	40	N15E	Closed	356.5	316.7	N9.8E	28.7	N10.4E
9	40	S75E	Open	51.2	11.3	S79.1E	0.8	S75.9E
25	40	N75W	Upright	408.3	368.4	N80.6W	36.0	N80.1W
26	60	N15E	Closed	228.3	168.9	N11.5E	10.2	N12.4E
28	60	S75E	Open	60.7	0.8	S48.7E	0.3	S74.7E
3	60	N75W	Upright	233.8	[illegible]	N67W	24.3	N69W
5	80	N15E	Closed	167.4	38.6	N28.2E	20.3	N22E

TABLE A.1 Continued

Preshot				Postshot				
No.	Distance From GZ	Bearing From GZ	Orientation	Distance From GZ	Displacement	Bearing From Pre-Shot Position	Perpendicular Distance[a]	Bearing From GZ
	ft			ft	ft		ft	
4	80	S75E	Open	81.1	1.4	S32.8E	1.0	S74.3E
15	80	N75W	Upright	174.5	94.6	N75W	0.0	N75W
11	100	N15E	Closed	127.9	28.0	N12.6E	1.2	N14.5E
20	100	S75E	Open	101.0	1.2	S43.7E	0.6	S74.6E
1	100	N75W	Upright	184.3	84.7	N68W	10.3	N71.8W
14	120	N15E	Closed	142.3	22.4	N18.8E	1.5	N15.6E
10	120	S75E	Open	120.3	0.9	N35.5E	0.8	S75.4E
17	120	N75W	Upright	174.8	55.2	N72.6W	7.3	N77.4W
23	140	N15E	Closed	176.4	37.5	N0.3W	9.9	N11.8E
8	140	S75E	Open	140.2	0.2	N74.7E	0.1	S75.1E
18	140	N75W	Upright	172.3	32.4	N78.2W	1.8	N75.6W
6	160	N15E	Closed	174.2	14.2	N17E	0.5	N15.2E
22	160	S75E	Open	159.9	0.1	N53.1W	0.1	S75E
24	160	N75W	Upright	168.6	8.8	N64.3W	1.6	N74.5W
19	180	N15E	Closed	183.0	3.0	N12.8E	0.1	N14.9E
29	180	S75E	Open	180.1	0.3	S19.1E	0.2	S74.9E
16	180	N75W	Upright	181.3	1.4	N53.7W	0.5	N74.8W
21	200	N15E	Closed	204.7	4.8	N14.5E	0.1	N15E
27	200	S75E	Open	199.9	0.5	S15.5W	0.5	S74.9E
12	200	N75W	Upright	201.0	1.1	N66.8W	0.2	N75W
1/4" x 12" Square Plate								
5	10	N30E		40.0	32.1	N13.1W	22.0	N3.3W
16	10	S60E		10.6	0.7	S22.4E	0.4	S57.7E
23	10	S60W		11.2	1.2	S54.6W	0.1	S59.4W
28	10	N60W		Not Located				
11	20	N30E		[illegible]0.8	341.1	N18.8E	66.3	N19.4E
18	20	S60E		[illegible]1.0	51.6	S43E	15.1	S47.7E
29	20	N60W		[illegible]0.2	0.5	S46.5W	0.5	N61.5W
4	40	N30E		[illegible]1.8	1.9	N9.1E	0.7	N29.1E
26	40	S60E		[illegible]1.6	21.6	S59.8E	0.1	S59.9E
24	40	N60W		[illegible]1.8	2.8	S68.1W	2.2	N63W
10	60	N30E		[illegible]7.2	32.1	N61.7W	32.1	N58.5E
17	60	S60E		[illegible]0.2	0.8	N49.2E	0.7	S60.7E
14	60	N60W		[illegible]4.0	96.4	N68.6W	14.4	N65.3W[b]
12	80	S60E		[illegible]0.1	0.7	N37.3E	0.7	S60.5E
15	80	N60W		[illegible]0.5	1.3	S50.5W	1.3	N60.9W
9	100	N30E		[illegible]0.0	2.0	N60.9W	2.0	N28.8E
27	100	S60E		[illegible]0.5	0.7	N75E	0.5	S60.3E
7	100	N60W		[illegible]1.9	314.7	S89.3W	160.9	N63.5W[b]
3	120	N30E		[illegible].1	1.5	N54.4W	1.5	N29.3E
8	120	S60E		[illegible].9	0.1	N48.8W	0.0	S60E

TABLE A.1 Continued

	Preshot			Postshot				
No.	Distance From GZ ft	Bearing From GZ	Orientation	Distance From GZ ft	Displacement ft	Bearing From Pre-Shot Position	Perpendicular Distance[a] ft	Bearing From GZ
13	120	N60W		123.3	3.4	N68.7W	0.5	N60.2W
6	140	N30E		140.3	1.7	N48.4W	1.6	N29.3E
19	140	S60E		139.8	0.3	S60E	0.2	S60.1E
22	140	N60W		140.0	1.3	S32.5W	1.3	N60.6W
1	160	N30E		160.0	1.3	N57.5W	1.3	N29.5E
20	160	S60E		159.6	0.5	N8.8W	0.4	S60.2E
25	160	N60W		165.0	14.2	N11.4E	13.5	N55.3W
2	180	N30E		179.7	1.7	N67.3W	1.7	N29.5E
30	180	N60W		182.2	2.3	N53.7W	0.3	N59.9W
21	200	S60E		199.1	1.0	N28.6W	0.5	S60.7E
4" x 4" x 3 1/2" LWH Steel Cube								
23	10	N15W		350.8	340.8	N15.7W	3.9	N15.7W
8	20	N45E		151.8	131.9	N41.7E	7.7	N42.1E
12	20	S40E		89.2	69.3	S46.7E	8.1	S45.2W
18	20	N45W		60.2	40.9	N27W	12.6	N32.9W
1	40	N45E		51.5	11.5	N40.3E	1.0	N43.9E
32	40	S40E		40.8	0.9	S11.9E	0.4	S39.4E
4	40	N45W		73.6	33.7	N50.1W	3.0	N47.3W
16	60	N45E		61.7	1.8	N27.4E	0.6	N44.5E
34	60	S40E		62.2	2.3	S54.8E	0.6	S40.5E
14	60	N45W		64.9	5.0	N40.4W	0.4	N44.7W
9	80	N45E		80.7	0.8	N63.4E	0.3	N45.2E
20	80	S40E		81.8	2.7	S7.5W	2.0	S38.6E
27	80	N45W		100.1	20.2	N49.8W	1.7	N46W
28	100	N45E		100.4	0.7	S83.3E	0.5	N45.3E
7	100	S40E		114.6	14.8	S33E	1.8	S39.1E
2	100	N45W		112.9	13.0	N41W	0.9	N44.5W
21	120	N45E		121.0	1.2	N47.2E	0.6	N45.3E
33	120	S40E		120.5	0.5	S53.6E	0.1	S39.9E
10	120	N45W		129.4	9.5	N40.9W	0.7	S44.7W
5	140	N45E		140.1	0.2	S73.3E	0.2	N45.1E
25	140	S40E		139.9	0.4	S44.9W	0.4	S39.9E
6	140	N45W		141.5	1.7	N21.8W	0.7	N44.7W
26	160	N45E		160.1	0.3	N85.4E	0.2	N41.1E
29	160	S40E		160.4	0.5	S66E	0.2	S40.1E
22	160	N45W		160.3	1.3	N29.7E	1.3	N44.6W
11	180	N45E		180.1	0.2	N45E	0.2	N45E
13	180	S40E		179.8	0.1	S40E	0.1	S40E
30	180	N45W		179.9	0.7	N48.7E	0.7	N44.8W
19	200	N45E		199.8	0.1	S4.1W	0.1	N45E
17	200	S40E		200.1	0.2	S19.8E	0.1	S40E
3	200	N45W		199.4	0.5	S65.8E	0.2	N44.9W

TABLE A.1 Continued

	Preshot			Postshot				
No.	Distance From GZ	Bearing From GZ	Orientation	Distance From GZ	Displacement	Bearing From Pre-Shot Position	Perpendicular Distance[a]	Bearing From GZ
	ft			ft	ft		ft	
15	122.5	S29.3W		130.1	7.6	S28.2W	0.2	S29.3W
24	121.9	S27.2W		131.8	10.0	S35.5W	1.5	S27.8W
31	123.0	S28.4W		130.8	7.8	S31.7W	0.5	S28.4W
5 1/2" x 5 1/2" x 5 1/2" LWH Wooden Blocks								
10	10	N67.30E		Not Located				
121	10	S30E		Not Located				
42	20	S30E		Not Located				
40	40	N67.30E		Not Located				
111	40	S30E		Not Located				
4	50	S60W	Parallel	Not Located				
6				68.6	18.7	S67W7	2.3	S62W
7				77.9	28.4	S48.2W	5.8	S55.7W
17				204.3	154.3	S57.9W	5.7	S58.4W
22	50	S60W	Parellel	Not Located				
23				261.5	213.7	S41.1W	69.3	S44.6W
24				123.8	76.1	S37.4W	29.2	S46.3W
26				144.0	94.1	S56.8W	5.2	S87.9W
28				205.0	156.3	S45.4W	39.5	S48.9W
29				204.9	156.2	S45.2W	39.9	S48.8W
31				359.9	311.4	S45.2W	79.6	S47.2W
36				Not Located				
38				472.1	459.2	N42W	449.1	N48W
43				257.1	212.9	S29 3W	108.7	S35W
45				235.8	186.0	S53.5W	21.0	S54.9W
59				72.2	22.3	S58.7W	0.5	S59.6W
61				Not Located				
65				Not Located				
71				180.5	133.8	S35.7W	55.0	S42.3W
76				234.8	188.9	S33.6W	84.0	S39.W
77				170.0	122.3	S39.8W	42.3	S45.6W
78				113.5	66.5	S86.3W	29.5	S75W
82	50	N30W	Perpendicular	608.4	558.4	N31W	9.3	N30.9W
86				Not Located				
88				617.2	567.2	N31.9W	18.7	N31.7W
93				578.9	529.0	N26.3W	34.5	N26.6W
94				614.7	564.8	N30.9W	8.4	N30.8W
96				675.6	630.5	N3.5W	281.4	N5.4W
97				633.7	584.1	N22.8W	73.5	N23.4W
98				760.7	710.9	N34.8W	59.9	N34.5W[c]
100				559.3	510.3	N18.4W	102.3	N19.5W
105				260.5	211.9	N15.1W	54.6	N17.9W
106				506.2	456.4	N34.5W	35.4	N34W
108				497.9	448.2	N35.9W	45.8	N35.3W

TABLE A.1 Continued

	Preshot			Postshot				
No.	Distance From GZ	Bearing From GZ	Orientation	Distance From GZ	Displacement	Bearing From Pre-Shot Position	Perpendicular Distance	Bearing From GZ
		ft		ft	ft		ft	
116				500.4	450.5	N26.2W	30.1	N26.6W
125				743.1	695.1	N46.9W	201.6	N45.7W
138				706.8	657.6	N40.7W	122.1	N39.9W
144				430.5	380.7	N24.5W	36.4	N15.2W
153				619.6	574.1	N4.4W	247.9	N6.4W
156				551.4	502.2	N18.8W	97.2	N19.9W
157	50	N30W	Perpendicular	515.2	466.1	N18.7W	91.7	N19.8W
159			Pile	610.1	562.3	N12.2W	171.8	N13.6W
161				617.7	567.8	N29.2W	8.0	N29.3W
162				Not Located				
19	60	N67.5E	Single	413.8	353.8	N67.2E	2.0	N67.2E
56	60	S30E		272.3	214.1	S14.2E	58.5	S17.6E
80	80	N67.5E		254.2	174.4	N60.7E	9.6	N69.7E
85	80	S30E		183.9	104.1	S34.3E	7.8	S32.4E
2	100	N67.5E		107.7	7.8	N57.5E	1.4	N66.7E
35	100	S30E		169.3	76.9	S4W	43.0	S15.3E
79	100	S75W	Parallel Pile	130.4	31.2	S60.2W	8.0	S71.5W
92				181.4	81.6	S80W	7.1	S77.3W
101				182.1	82.5	S81.6W	9.4	S78W
107				192.1	93.4	S81.3W	21.2	S88.1W
109				197.9	98.3	S71.3W	12.7	S67.5W
110				259.4	159.5	S71.4W	10.0	S72.8W
112				Not Located				
115				276.9	177.6	S67.2W	24.1	S70W
117				135.3	35.5	S69W	3.7	S73.4W
122				173.5	73.5	S76.3W	1.6	S75.5W
123				148.4	54.0	S52.7W	28.9	S63.8W
124				135.0	35.2	S68.6W	3.9	S73.3W
128				Not Located				
130				182.1	82.4	S81W	8.6	S77.7W
131				226.6	148.6	S25.5W	113.0	S45.1W
132				274.2	174.2	S75.6W	1.9	S75.4W
137				155.9	56.0	S70.4W	4.5	S73.4W
137A				176.4	76.8	S82.6W	10.1	S78.3W
147				205.5	105.6	S79.3W	7.9	S77.2W
148				200.1	100.3	S79.4W	7.7	S77.2W
149				153.8	54.7	S87.6W	11.9	S79.5W
154				166.7	156.5	S27.4E	152.8	S8.5W
163				184.7	84.8	S77.4W	3.6	S76.1W
1	100	N30W	Perpendicular	407.1	316.3	N1.7W	150.1	N8.4W
8	-		Pile	427.1	329.8	N15W	85.2	N18.5W
9				398.8	299.6	N37.9W	41.4	N35.9W

TABLE A.1 Continued

	Preshot			Postshot				
No.	Distance From GZ ft	Bearing From GZ	Orientation	Distance From GZ ft	Displacement ft	Bearing From Pre-Shot Position	Perpendicular Distance[a] ft	Bearing From GZ
10				201.4	103.6	N46.5W	29.3	N38.4W
11				385.7	293.8	N56.7W	132.0	N50W
16				377.8	279.0	N19.9W	48.7	N22.4W
21				474.1	382.6	N56.5W	170.8	N51.1W
32				Not Located				
37				402.1	304.2	N43.5W	70.8	N40.1W
39				386.0	286.0	N31.5W	7.5	N31.1W
40				546.9	453.5	N53W	177.2	N48.9W
41				417.4	327.3	N0.7W	159.9	N7.5W
44				394.4	294.5	N32.5W	12.7	N31.9W
44[d]				440.9	344.5	N12.6W	103.3	N16.5W
46				615.2	520.3	N49.9W	177.3	N46.8W
48				380.9	287.5	N5.9W	117.5	N12W
50				338.6	238.9	N34.5W	18.6	N33.1W
50[d]				316.5	216.9	N35.8W	21.9	N34W
54				398.8	299.1	N34.3W	22.6	N33.2W
55				402.6	307.6	N50.9W	109.6	N45.8W
47				263.3	163.4	N27.6W	6.8	N28.5W
58				560.3	460.3	N29.2W	6.3	N29.4W
66				332.7	232.8	N32.4W	9.9	N31.7W
66[d]				203.9	103.9	N29.6W	0.7	N29.8W
68				519.1	419.1	N31W	7.3	N30.8W
145	120	N67.5E	Single	151.2	31.2	N66.3E	0.7	N67.2E
90	120	S30E		118.8	2.8	N35.3E	2.6	S31.2E
5	140	N67.5E		148.1	8.6	N47.8E	2.9	N66.4E
12	140	S30E		176.3	36.4	S31E	0.7	S30.2E
81	150	N30W	Perpendicular	361.6	221.8	N57.4W	102.0	N46.4W
84			Pile	345.7	195.8	N31.2W	4.2	N30.7W
87				342.4	200.6	N5W	84.8	N15.3W
99				218.3	69.2	N41W	13.2	N33.5W
102				264.1	125.0	N62.4W	66.9	N44.7W
103				330.27	181.4	N39.3W	29.4	N35.1W
113	150	N30W	Perpendicular	446.4	305.5	N5.6W	126.1	N13.6W
118			Pile	Not Located				
120				263.6	115.7	N15.6W	28.9	N23.7W
129				306.9	160.9	N48.2W	50.3	N39.4W
136				404.2	260.9	N8.5W	95.5	N16.3W
140				182.5	38.1	N65.1W	21.9	N36.9W
141				314.1	167.2	N13.9W	46.3	N21.5W
142				383.9	234.0	N32.3W	9.3	N31.4W

TABLE A.1 Continued

	Preshot			Postshot				
No.	Distance From GZ	Bearing From GZ	Orientation	Distance From GZ	Displacement	Bearing From Pre-Shot Position	Perpendicular Distance[a]	Bearing From GZ
	ft			ft	ft		ft	
143				328.6	184.5	N8.4W	68.0	N18.1W
146				382.4	239.6	N52.6W	92.2	N44W
150				314.2	164.4	N34.4W	12.5	N32.3W
151				410.6	266.7	N9.5W	93.4	N16.2W
152				244.4	96.2	N15.8W	23.6	N24.5W
155				393.6	248.9	N49.4W	82.5	N42.1W
160				296.8	147.3	N23.4W	17.0	N26.7W
164				208.4	60.8	N49.1W	19.9	N35.5W
3	150	S75W	Parallel Pile	152.9	3.4	S44.1W	1.8	S74.3W
13				184.2	34.5	S82.6W	4.6	S76.4W
14				153.8	3.9	S64W	0.8	S74.7W
18				151.0	1.7	S24.3W	1.3	S74.5W
20				168.5	18.9	S63.7W	3.7	S73.7W
27				167.8	17.9	S69W	1.9	S74.6W
30				155.0	6.7	S33.4W	4.4	S73.4W
33				149.8	1.3	S22.9W	1.3	S74.5W
34				157.4	7.4	S72.6W	0.3	S74.9W
49				154.4	4.6	S63.5W	1.3	S74.5W
52				Not Located				
53				150.5	1.3	S9.5W	1.2	S74.5W
60				156.7	7.5	S49.2W	3.3	S73.8W
62				153.7	4.4	S43.4W	2.3	S74.1W
63				159.7	9.8	S73.1W	0.3	S74.9W
64				151.5	1.7	S49.8W	0.7	S74.7W
67				155.3	6.2	S46.3W	3.0	S73.9W
70	150	S75W	Parallel File	157.8	9.5	S39.9W	5.4	S73W
72				157.5	7.9	S59.3W	2.1	S74.2W
73				151.5	1.5	S74.1W	0.0	S75W
74				154.4	4.5	S69.9W	0.4	S74.8W
75				184.6	35.0	S84.6W	5.8	S76.8W
89	160	N67.5E	Single	160.4	0.5	N44.2E	0.2	N67.4E
119	160	S30E		165.4	5.8	S50.2E	2.0	S30.7E
51	180	N67.5E		249.44	106.2	N6.5E	92.9	N45.5E
15	180	S30E		188.7	8.8	S35.3E	0.8	N30.3E
91	200	N67.5E		203.2	3.4	N52.1E	0.9	N67.3E
114	200	S30E		200.3	0.4	S33.2E	0.0	S30E
133[e]	122	S32W	On Platform	Not Located				
25[e]	128	S28W		Not Located				
134[e]	129.2	S27.6W		307.2	181.6	S45.2W	54.8	S37.9E
165[e]	129.2	S27.6W		422.9	295.2	S38W	53.1	S34.8E

a
b Measurement made from original radial line perpendicular to terminal location
c Data appears to be incorrect
d Farthest displaced object located
e Blocks listed twice were located in two equal masses at different terminal points
Objects positioned on concrete pad

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